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Performance Analysis of RAW Impact on IEEE 802.11ah Standard Affected by Doppler Effect

A.A. Marwan, D. Perdana, D.D. Sanjoyo

Abdul Aziz Marwan*
Department of Electrical Engineering, Telkom University
Jl. Telekomunikasi No. 1 Terusan Buah Batu 40257, Bandung, Indonesia
*Corresponding author: abdulazizmarwan@student.telkomuniversity.ac.id

Doan Perdana
Department of Electrical Engineering, Telkom University
Jl. Telekomunikasi No. 1 Terusan Buah Batu 40257, Bandung, Indonesia
doanperdana@telkomuniversity.ac.id

Danu Dwi Sanjoyo
Department of Electrical Engineering, Telkom University
Jl. Telekomunikasi No. 1 Terusan Buah Batu 40257, Bandung, Indonesia
danudwj@telkomuniversity.ac.id

Abstract: Internet of Things (IOT) offers a new dimension of technology and information where connectivity is available anywhere, anytime, and for any purpose. IEEE 802.11 Wireless Local Area Network group is a standard that developed to answer the needs of wireless communication technology (WI-Fi). Recently, IEEE 802.11 working group released the 802.11ah technology or Wi-Fi HaLow as a Wi-fi standard. This standard works on the 1 GHz frequency band with a broader coverage area, massive device and the energy efficiency issues. This research addresses, the influence of Doppler Effect using Random Waypoint mobility model on 802.11ah with different RAW slot and RAW slot duration are analyzed. The design of the simulation system is done by changing RAW slot and RAW slot duration. Based on the result, it can be concluded that the overall performance of the network with all of the parameter scenarios is decreasing along with the increasing RAW slot, RAW slot duration, and fluctuation. In the RAW slot = 5 scenario with v = 10 km/h has the worst performance with an average delay which is about 0.128225 s, and average throughput is about 0.284337 Mbps while for RAW slot = 1 with an average PDR which is about 99.1076 %. While in the RAW slot duration = 0.020 s scenario with v = 10 km/h has the worst performance with an average delay which is about 0.135581 s, average throughput is about 0.286828 Mbps, and average PDR which is about 99.3165 %.
Keywords: Restricted Access Window (RAW), IEEE 802.11ah, Random Waypoint, Modulation and Coding Scheme (MCS), Network Simulator 3.

1 Introduction

Nowadays, Internet of Thing (IoT) offers a new dimension in the world of technology and information where connectivity is available wherever, whenever, and for anything. The current global trend of Internet of Thing is very rapidly evolving from the needs of users that want the efficiency of devices in various aspects in order to facilitate the user's own activities [2]. The number of connected devices being the main point of problems in IoT technology itself related to energy efficiency or energy consumption.

The IEEE 802.11 Wireless Local Area Network standard working group operating at 2.4 GHz and 5 Ghz band frequencies is a standard that developed to address the needs for wireless

(Wi-Fi) communication technology problems that have a high data rate, easy to develop and lower value in cost aspect, such as Wireless Sensor Network (WSN) and Machine to Machine (M2M) communication that used in application of military, commercial, health care, monitoring of traffic, and also controlling the inventory [1]. In its development, the IEEE 802.11 working group released 802.11ah or Wi-fi HaLow technology as the new Wi-fi standard. This standard works on a 1 GHz band frequency with broader area coverage, more effective in cost value with an energy efficiency improvement [9]. 802.11ah provides a shortest MAC header, segmented traffic indication map (TIM), restricted access window (RAW), and target wake time (TWT) that support the efficiency and quantity of energy used by stations (STAs) [7].

In its application, 802.11ah technology can accommodate devices or stations in large numbers and every station has their movement pattern such as static or mobile user characteristics. The movement of stations or mobility can affect the performance of the 802.11ah itself. The most commonly used mobility model according to the literature is the Random Waypoint (RMW) model [8]. Firstly, each station will go to the random destination with random speed, move towards the destination, and pause on several times, then moving again towards the coordinates of the destination. Other similar mobility models such as Random Direction model, the Random Walk model, Manhattan and the Gauss-Markov mobility model are also often used in experimental simulations to obtain data that represent real condition network in the world [5]. The term fading means the signal information is being lost on the process of transferring. This can be happened because of some factors such as rapid fluctuation of amplitudes, phases, multipath delays, or user speed. This user speed factor is the Doppler Effect that influencing fading of the signal. The Doppler Effect is a relative motion between the base station and the user which results in random frequency modulation due to different Doppler shifts on each of the multipath components [3].

In this research we discuss about the Doppler Effect with the changing of RAW schemes on IEEE 802.11ah standard network performances using Random Waypoint Mobility model with velocity = 10 km/h. This scenario aims to analyze the performance of RAW impact on 802.11ah and to find the RAW with the worst performance. The RAW schemes are using the RAW slot = 1, 2, 3, 4, 5 and RAW slot duration = 0.005 s, 0.010 s, 0.015 s, 0.020 s. Furthermore, the performance of network is measured using simulation result from Network Simulator 3. The measured output are delay, throughput, and PDR.

2 General description of the used mechanisms

The simulations on this research were performed on Network Simulator 3 release 3.21 with 802.11ah module which has been modified according to [10]. The RAW scenario aims to analyze the Doppler Effect on 802.11ah with different RAW duration and RAW slot. Simulations were performed on 100 nodes with 50 RAW stations. On each number of station, the simulation were performed in two different RAW slot scenarios, and on each RAW slot duration, the simulation were performed in five different RAW slot number as explained in table 1.

The amount of bandwidth and data rate used in the simulation is adjusted to be about twice than the other. Which is MCS 3 (2 MHz bandwidth and 2600 Kbps data rate). Effective and efficient network conditions are required by wireless networks with IEEE 802.11ah standards that capable of allocating stations with large numbers and wide coverage.

In the simulation topology, was placed one Access Point and 100 nodes of STA around it that illustrated in Fig 1. This research focuses on RAW mechanism in MAC layer of 802.11ah standard. The other features such as TIM segmentation and TwT were not implemented.

The simulation has used the Traffic Generator as a sender as well as a receiver packets that will be delivered. Generation of traffic is done by UDP transport protocol because when data is

Figure 1: Topology of Simulation

Table 1: Scenario Explanation

	Slot duration = 0.005 s	Slot = 1
		Slot = 2
		Slot = 3
		Slot = 4
		Slot = 5
	Slot duration = 0.010 s	Slot = 1
		Slot = 2
		Slot = 3
		Slot = 4
		Slot = 5
RAW Scenario	Slot duration = 0.015 s	Slot = 1
		Slot = 2
		Slot = 3
		Slot = 4
		Slot = 5
	Slot duration = 0.020 s	Slot = 1
		Slot = 2
		Slot = 3
		Slot = 4
		Slot = 5

transmitted, data transmission time is more important than its integrity [4], it is in accordance with the needs of delivery data on IoT communications where communication in real time is necessary.

The flowchart system of this research is presented in figure 2. According to the system, after designing the simulation of 802.11ah standard in NS3 environment, traffic generator is implemented on the simulation. The RAW changing scenario of simulation is designed to collect the data. If the scenarios are succeeded, delay, throughput and PDR data can be collected to be analyzed. Thus, the Doppler Effect influence on network performance can be analyzed for the conclusion.

The output from the simulation in this research is QoS parameters which are as follows [6]:

- Average End to End Delay, which is the average time of delivering the data package from the sender to the receiver.

$$Delay = \frac{\sum Receivedpacketdestination - Packetsentsource}{\sum Packetreceived} \tag{1}$$

- Throughput, which is defined as the speed (rate) effective for transferring the data. Throughput is total number of packets received in bits divided by the number of delivery time.

$$Throughput = \frac{\sum Receivedpacketsize}{\sum Deliverytime} \tag{2}$$

- Packet Delivery Ratio (PDR), which is the ratio between the numbers of packets successfully received and the number of packets sent.

$$PDR = \frac{\sum Totalpacketreceived}{\sum Totalpacketsent} \times 100\% \tag{3}$$

3 Experimental results

The parameters and its description of the simulation are presented in table 2. The output from the simulation is QoS parameters such as delay, throughput, and PDR for RAW slot and RAW slot duration scenario in IEEE 802.11ah standard using Random Waypoint mobility with $v = 10km/h$ which are shown in figure 3 - figure 5.

The Doppler Effect is calculated to find which of the small-scale fading are affected by the RAW slot and RAW slot duration. The impacts are Delay Spread that causing signal power to be weakened and Inter-Symbol Interference (ISI), Doppler Spread that causing signal power to be weakened, and Doppler Shift that causing frequency signal wave to be changed or distorted.

The first influence of Doppler Effect is Delay Spread: Frequency Selective Fading which is about $40 \times 10^{-6}s << 2 \times 10^{-3}s$ or $Ts << \sigma$, where symbol duration is lower than maximum excess delay and $2MHz >> 0,1MHz$ for MCS 3 or $Bs >> Bc$, where bandwidth of signal is higher than channel bandwidth. And the second influence of Doppler Effect is Doppler Spread: Slow Fading which for $v = 10km/h$ is about $21 \times 10^3 \mu s >> 40 \mu s$ or $Ts >> Tc_{10}$, where symbol duration is lower than time coherence channel. And the third influence of Doppler Effect is Doppler Shift which for $v = 10km/h$ is about $-8,521Hz$ to $8,521Hz$, where the sender frequency signal wave is distorted.

Figure 3 shows the influence of Doppler Effect in increasing the number of RAW slot and RAW slot duration to the delay that obtained from simulations with MCS 3 (2 MHz bandwidth and 2600 Kbps data rate) using v = 10 km/h user speed. There are some fluctuations in both RAW slot and RAW slot duration. This is the impact of Doppler Spread: Slow Fading causing the delay value in both RAW slot and RAW slot duration to be fluctuated. From the graph above, the highest value of delay that obtained from MCS 3 in RAW slot = 5 with an average delay which is about 0.128225 s while in RAW slot duration = 0.020 s with an average delay which

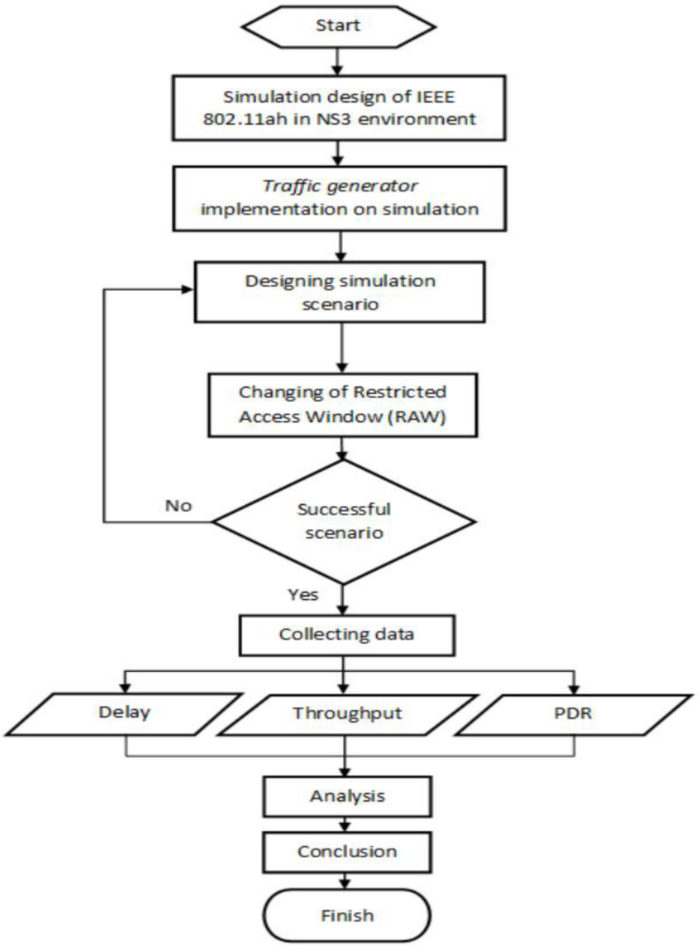

Figure 2: Flowchart System

Table 2: Simulation Parameters

Parameters	**Value**
Physical Layer	WLAN/ IEEE 802.11ah
Transport Layer	UDP
Payload Size	100 Bytes
Rho	100 m
Number of STA	100
Number of RAW STA	50
Number of AP	1
MCS	MCS 3 (2 MHz bandwidth and 2600 Kbps data rate)
RAW Group	1
RAW Slot	1, 2, 3, 4, 5
RAW Slot duration	0.005 s, 0.010 s, 0.015 s, 0.020 s
Mobility Model	Random Waypoint Mobility
User Speed	10 km/h

is about 0.135581 s. Also, the highest fluctuation value of delay that obtained in RAW slot = 5 with an average delay which is about 0.501875 s while in RAW slot duration = 0.020 s with an average delay which is about 0.300501 s. In this scheme, from the result in the terms of average delay, that the network performance is getting lower with the increasing number of RAW slot and RAW slot duration. Meanwhile the fluctuation is getting higher with the increasing number of RAW slot and RAW slot duration. Thus, the higher the fluctuation in delay, the lower the network performance will be in higher RAW slot and RAW slot duration.

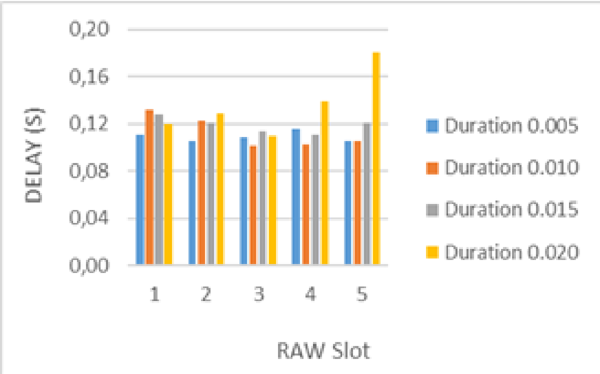

Figure 3: Delay on v = 10 km/h user speed

Figure 4 shows the influence of Doppler Effect in increasing the number of RAW slot and RAW slot duration to the throughput that obtained from simulations with MCS 3 (2 MHz bandwidth and 2600 Kbps data rate) using v = 10 km/h user speed. There are some fluctuations in both RAW slot and RAW slot duration. This is the impact of Doppler Spread: Slow Fading causing the throughput value in both RAW slot and RAW slot duration to be fluctuated. From the graph above, the lowest value of throughput that obtained from MCS 3 in RAW slot = 5 with an average throughput which is about 0.284337 Mbps while in RAW slot duration = 0.020 s with an average throughput which is about 0.286828 Mbps. Also, the highest fluctuation value of throughput that obtained in RAW slot = 5 with an average throughput which is about 0.124824 Mbps while in RAW slot duration = 0.020 s with an average throughput which is about 0.125177 Mbps. In this scheme, from the result in the terms of average throughput, that the network performance is getting lower with the increasing number of RAW slot and RAW slot duration. Meanwhile the fluctuation is getting higher with the increasing number of RAW slot and RAW slot duration. Thus, the higher the fluctuation in throughput, the lower the network performance will be in higher RAW slot and RAW slot duration.

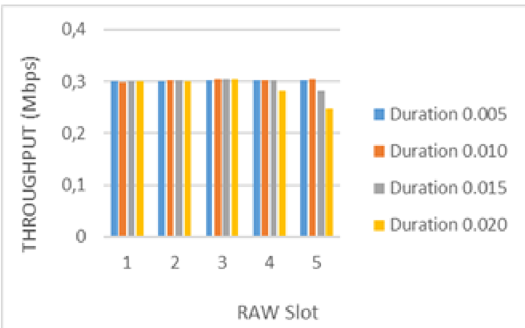

Figure 4: Throughput on v = 10 km/h user speed

Figure 5 shows the influence of Doppler Effect in increasing the number of RAW slot and

RAW slot duration to the PDR that obtained from simulations with MCS 3 (2 MHz bandwidth and 2600 Kbps data rate) using v = 10 km/h user speed. There are some fluctuations in both RAW slot and RAW slot duration. This is the impact of Doppler Spread: Slow Fading causing the PDR value in both RAW slot and RAW slot duration to be fluctuated. From the graph above, the lowest value of PDR that obtained from MCS 3 in RAW slot = 1 with an average PDR which is about 99.1076 % while in RAW slot duration = 0.020 s with an average PDR which is about 99.3165 %. Also, the lowest fluctuation value of PDR that obtained in RAW slot = 1 with an average PDR which is about 0.0006 % while in RAW slot duration = 0.020 s with an average PDR which is about 0.0019 %. In this scheme, from the result in the terms of average PDR, that the network performance is getting lower with the decreasing number of RAW slot and increasing RAW slot duration. Meanwhile the fluctuation is getting lower with the decreasing number of RAW slot and increasing RAW slot duration. Thus, the lower the fluctuation in PDR, the lower the network performance will be in lower RAW slot and in higher RAW slot duration.

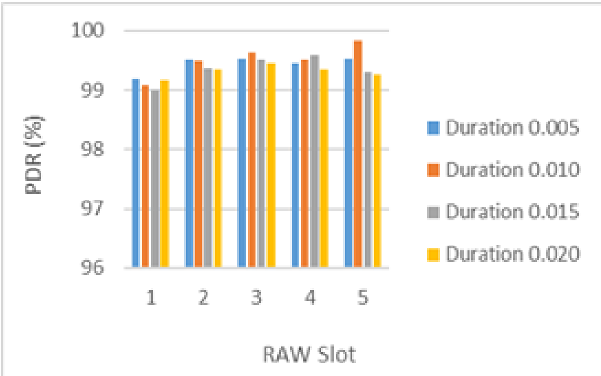

Figure 5: PDR on v = 10 km/h user speed

4 Conclusions

In the RAW scenario, the network performance value will decrease along with the increasing RAW slot and RAW slot duration. This is because the higher the RAW slot and RAW slot duration, the stronger the influence of Doppler Effect which caused the fluctuation. Based on the calculation, the lower the time coherence channel, the stronger the Doppler Spread: Slow Fading.

For delay, the network performance is getting lower with the increasing number of RAW slot and RAW slot duration. Meanwhile the fluctuation is getting higher with the increasing number of RAW slot and RAW slot duration. Thus, the higher the fluctuation in delay, the lower the network performance will be in higher RAW slot and RAW slot duration.

For throughput, the network performance is getting lower with the increasing number of RAW slot and RAW slot duration. Meanwhile the fluctuation is getting higher with the increasing number of RAW slot and RAW slot duration. Thus, the higher the fluctuation in throughput, the lower the network performance will be in higher RAW slot and RAW slot duration.

For PDR, the network performance is getting lower with the decreasing number of RAW slot and increasing RAW slot duration. Meanwhile the fluctuation is getting higher with the decreasing number of RAW slot and increasing RAW slot duration. Thus, the lower the fluctuation in PDR, the lower the network performance will be in lower RAW slot and in higher RAW slot duration.

It can be concluded that for network performance in delay and throughput, the network performance is getting lower with the increasing number of RAW slot and RAW slot duration. While in PDR, the network performance is getting lower with the decreasing number of RAW slot and increasing RAW slot duration. And for fluctuation in delay and throughput, the fluctuation is getting higher with the increasing number of RAW slot and RAW slot duration. While in PDR, the fluctuation is getting higher with the decreasing number of RAW slot and increasing RAW slot duration. Therefore, the fluctuation can be an indicator to analyze which RAW slot and RAW slot duration with the worst network performance where the fluctuation is the impact of the Doppler Effect.

Author contributions. Conflict of interest

The authors contributed equally to this work. The authors declare no conflict of interest.

Bibliography

[1] Aljarrah, E. (2017). Deployment of multi-fuzzy model based routing in RPL to support efficient IoT, *Int. J. Commun. Networks Inf. Secur.*, 9(3), 457-465, 2017.

[2] Khan, I. (2017). Performance Analysis of 5G Cooperative-NOMA for IoT-Intermittent Communication, *Int. J. Commun. Networks Inf. Secur.*, 9(3), 314-322, 2017.

[3] Mitra, A. (2009). *Lecture Notes on Mobile Communication: A Curriculum Development Cell Project Under QIP*, IIT Guwahati, India, 2009.

[4] Olariu, C. (2013). *Quality of Service Support for Voice over IP in Wireless Access Networks*, Waterford Institute of Technology, 2013.

[5] Perdana, D; Munadi, R.; Manurung, R.C. (2017). Performance Evaluation of Gauss-Markov Mobility Model in Hybrid LTE-VANET Networks, *Telkomnika(Telecommunication Computing Electronics and Control)*, 15(2), 606-621, 2017.

[6] Putra, M.A.P.; Perdana, D.; Negara, R.M. (2017). Performance Analysis of Data Traffic Offload Scheme on Long Term Evolution (LTE) and IEEE 802.11AH, *Telkomnika(Telecommunication Computing Electronics and Control)*, 15(4), 1659-1665, 2017.

[7] Raeesi, O.; Pirskanen, J.; Hazmi, A.; Levanen, T.; Valkama, M. (2014). Performance evaluation of IEEE 802.11ah and its restricted access window mechanism, *Proc. IEEE ICC Workshops*, 460-466, 2014.

[8] Rupinder, K.; Gurpreet, S. (2014). Survey of Various Mobility Models in VANETs, *Int. J. Eng. Comput. Sci.*, 3(3), 4073-4080, 2014.

[9] Sun, W.; Choi, M.; Choi, S. (2014). IEEE 802.11ah: A Long Range 802.11 WLAN at Sub 1 GHz, *J. ICT Stand.*, 2(2), 83-108, 2014.

[10] Tian, L.; Deronne, S.; Latre, S.; Famaey, J. (2016). Implementation and Validation of an IEEE 802.11ah Module for ns-3, *Conf. Work. ns3 (WNS3), Seattle, USA*, 49-56, 2016.